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TESTING FOR LONG RUN MONEY DEMAND FUNCTIONS
IN GREECE USING COINTEGRATION TECHNIQUES

by

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No. 151 NOVEMBER 1990

DEPARTMENT OF ECONOMICS

The University of Sydney
Australia 2006

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**ABSTRACT**

Long run money demand functions for M1 and M3 are tested by means of the cointegration methodology developed by Johansen (1988). The results support the existence of an economically meaningful cointegrating vector for both measures of monetary aggregates. The rejection of a unit price elasticity of money demand suggests that money is not neutral in Greece. The significance of interest rate elasticity of M3 implies that the aggregate is subject to control through policy-induced interest rate movements and thus can serve as a useful monetary target.

National Library of Australia Card Number and ISBN 0 86758 380 0

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# I. INTRODUCTION

The specification and stability of the money demand equation has been extensively investigated over the last decade for a number of countries (Laider,1980, Brissimis and Levendakis,1981, Den Butter and Fase,1981, Artis and Lewis,1984, Roley,1985, Swamy and Tavlas,1989). A substantial amount of the research effort devoted to analysing theoretical money demand specifications has concentrated on the role of money acting as a buffer stock asset which absorbs unforeseen monetary shocks disturbing the balance between receipts and payments (Carr and Darby,1981, Cuthbertson and Taylor,1984, Cuthbertson,1988, Muscatelli,1988). On the other hand, the error correction (EC) model has become a very popular empirical specification for dynamic money demand equations (Hendry,1979, Gondon,1984).

The structural stability of money demand is a key ingredient in formulating a monetary policy based on intermediate targets. Unless the money demand is structurally stable, any attempt to disinflate the economy through monetary control will not be successful, since different inflation rates will be consistent with a given money stock.

For a monetary aggregate to be useful as an intermediate target, there should exist some sort of equilibrium relationship between it and other macroeconomic variables, such as prices, output and interest rates. An implication of this long run relationship is that shocks to money are reflected on prices, output and interest rates in a similar way.

Since the mid-1970s the Greek monetary authorities have attempted to disinflate the economy by relying on intermediate targets for various financial aggregates (see Karfakis, 1988).

What the present paper addresses is to test whether the existence of a money market equilibrium for the narrow (M1) and broad (M3) measures of monetary aggregates, is consistent with the time series analysis of the Greek data by means of cointegration tests developed by Johansen (1988). If the hypothesis of a noncointegrating money market vector it is not rejected, then the analysis will use both EC and Phillips-Hansen (1990) methodologies to test the statistical significance of the long run multipliers.

## II. UNIT ROOT TESTS, COINTEGRATION AND MODELLING OF LONG RUN MONEY DEMAND

It is an empirical fact that many macroeconomic time series are characterised by nonstationarities, implying that the classical *t*-test and *F*-test are inappropriate because the limiting distribution of the asymptotic variance of the parameter estimates is not finitely defined (Fuller, 1985). Appropriate tests have been developed by Fuller (1976), Dickey and Fuller (1981) to test whether a nondeterministic series it is integrated

of order one (henceforth I(1)) against the alternative of zero order integration (I(0)). The technique is to estimate the regression

$$\Delta X_t = aX_{t-1} + b + e_t \tag{1}$$

with $e_t \sim IN(0, \sigma^2_e)$, and then test the hypothesis $H_0: a=0$ by comparing the calculated *t*-ratio of $\hat{a}$ with the reported percentiles in Fuller (1976, p.373). This is known as the Dickey-Fuller (henceforth DF) test. If however, $e_t$ is not approximately white noise, Dickey and Fuller (1981) have suggested to enlarge model (1) by adding in a lag polynomial in $\Delta X_t$ as a means of removing serial correlation.[1] The reported percentiles in Fuller (1976) can also be used for the *t*-ratio of $\hat{a}$ in the augmented regression (ADF test). Recently, Phillips (1987), Perron (1988), and Phillips and Perron (1988) -henceforth PP- proposed nonparametric tests which allow for weakly dependent and heterogenous disturbances.

The long run linkage between a number of series can be looked at from the viewpoint of cointegration (Engle and Granger, 1987). Let $\mathbf{x}_t$ be a vector of n-component time series each integrated of the same order k. Then $\mathbf{x}_t$ is said to be cointegrated of order k,p, if there exists a vector $\lambda$ such that:

$$w_t = \lambda' x_t \tag{2}$$

is I(k-p), p>0. $\mathbf{w}_t$ being I(0) implies that the n variables of $\mathbf{x}_t$ do not drift away from one another over the long run, obeying thus an equilibrium relationship. If $\lambda$ exists, it will not be unique as there can be several equilibrium relationships linking n>2 variables. Engle and Granger (1987) have suggested a testing procedure for cointegration in the case where n=2. Recent advances in cointegration theory (Johansen,1988, Johansen and Juselius,1990) have developed tests regarding both the number of cointegrating vectors and hypotheses with respect to the elements of these vectors. The procedure is based on regressing the n-element vectors $\Delta\mathbf{x}_t$ and $\mathbf{x}_{t-q}$ on a constant and $\Delta\mathbf{x}_{t-i}$, i=1,...,q-1, and obtaining the associated n-element residual vectors $R_{0t}$ and $R_{qt}$. The test statistic for the number of cointegrating vectors is obtained by solving the eigenvalue problem

$$|\lambda S_{qq} - S_{q0}S_{00}^{-1}S_{0q}| = 0$$

where $S_{ij}=T^{-1}\sum_{t=1}^{T}R_{it}R_{jt}$, $\quad$ i,j=0,q

and T denotes the number of obserbations.[2]

The likelihood ratio (LR) statistic

$$-2lnQ=-T\sum_{i=r+1}^{n}\ln(1-\hat{\lambda}_i) \qquad (3)$$

is a test that there are at most **r** cointegrating vectors versus the general alternative (trace), where $\lambda_i$ corresponds to the n-r smaller eigenvalues. The nxr matrix of cointegrating vectors $\Phi$ can be obtained as the

**r** n-element eigenvectors corresponding to $\lambda_i$.

The LR statistic for testing that there are **r** versus **r**+1 cointegrating vectors is based on the maximum eigenvalue and given by:

$$-2\ln(Q:r|r+1)=-Tln(1-\hat{\lambda}_{r+1}) \qquad (4)$$

The LR statistics (2) and (3) based on the trace and the maximal eigenvalue respectively, have nonstandard distributions. Johansen (1988), and Johansen and Juselius (1990) have derived appropriate critical values. Tests of hypotheses regarding individual elements of the eigenvectors are also developed in Johansen and Juselius (1990). The LR test statistic for the hypothesis $H_0$:$\mathbf{\Phi}$=$\mathbf{H\Theta}$, where **H** is a nxs matrix of known restrictions and $\Theta$ is an sxr matrix of parameters which incorporates the restrictions on the individual values of the eigenvectors, is given by:

$$-2lnQ=T\sum_{i=1}^{r}((1-\hat{\lambda}^{*}_{i})/(1-\hat{\lambda}_{i})) \qquad (5)$$

where $\lambda_i^*$ corresponds to the r largest eigenvalues of the matrix $H'S_{q0}S_{00}^{-1}S_{0q}H$ with respect to $H'S_{qq}H$. The asymptotic distribution of this statistic is $X^2$ with r(n-s) degrees of freedom.

The first specification of the log-linear money demand equation tested for cointegration is given by:

$$m_t=\alpha_0+\beta_0 p_t+\gamma_0 y_t-\delta_0 R_t+u_{0t} \qquad (6)$$

where $\alpha_0$ is a constant, and $m_t$, $p_t$, $y_t$ denote the logs of the nominal money balances, the price level and the real income respectively. $R_t$ is the interest rate and $u_{0t}$ is the error term. Equation (6) assumes that the long run demand for nominal money balances depends positively on the price and income levels, and negatively on the rate of return which proxies the opportunity cost of holding money balances. Since $R_t$ (and the entire term structure) has been regulated over the sample period, a good proxy for the actual cost of holding money is difficult to be found.[3]

An alternative form of the long run money demand function, which includes the log of the effective exchange rate of the Greek drachma ($\varepsilon_t$) as a regressor, is also considered:

$$m_t=\alpha_1+\beta_1 p_t+\gamma_1 y_t-\delta_1 R_t+\zeta_1\varepsilon_t+u_{1t} \qquad (7)$$

where all the variables are defined as above, and $u_{1t}$ is the error term. Equation (7) assumes that a depreciation of the effective rate (i.e., a fall in the rate) reduces the demand for nominal money balances.

The money demand functions are specified in nominal terms, since price homogeneity is to be tested as a long run restriction. If it is not rejected, the empirical analysis will be carried out for real money balances. An additional restriction which is tested is that of real income homogeneity.

## III. EMPIRICAL RESULTS

Quarterly seasonally unadjusted data on M1 (currency in circulation plus private sight deposits) and M3 (M1 plus private savings and time deposits) measures of monetary aggregates, the gross domestic product (Y) at constant 1970 price, the consumer price index (P), the three-six month time deposit rate (R) and the effective exchange rate of the Greek drachma (E) are used over the period 1975.1-1988.3 during which a managed floating regime has been adopted.[4]

With respect to the unit root test results, the DF and PP statistics reported in Table 1, indicate that the generating mechanisms of the levels of all the series concerned are well approximated by a random walk.[5]

Having established the univariate time series properties of all the variables, the following model is fitted to the data:

$$\Delta X_t=d_0+d_1\Delta X_{t-1}+\ldots+d_{q-1}\Delta X_{t-q+1}+d_q X_{t-q}+\mu' D_{1t}+\omega_t \qquad (8)$$

where $X=m1,m3,p,y,R,\varepsilon$; $\mu$ is a 3x1 vector of parameters and D is a 3x1 vector of seasonal dummies; $\omega_t \sim IN(0,\sigma^2_\omega)$. Table 2 reports the selected lag length (q) for each equation and the associated Q-statistics for testing the presence of serial correlation. For q=2 (q=3), the residuals in the equations associated with m1 (m3) data pass the test for being uncorrelated. Since the parameter estimates of model (8) are not of particular interest are not reported.

The two set of regressions which discussed in section II are then fitted to the data. Initially, the constant term is unrestricted and thus included among the regressors. This implies that $\alpha_0$ is excluded from model (6). The results of testing for the number of cointegrating vectors in model (6) are reported in the first and third panels of Table 3. The LR test statistics that there are zero cointegrating vectors reject the null hypothesis against the 95% critical value for both m1 and m3. Moreover, the null hypothesis that there is at most one cointegrating vector is also rejected at the same level of significance. The LR tests that there are at most two or three cointegrating vectors accept the hypothesis that at least two but possibly three cointegrating vectors are present in the Greek money demand data.

The LR test results of the maximum eigenvalue reported in the first and third panels of Table 3 suggest that there are two cointegrating vectors for both m1 and m3 data, although only the signs of the second vector appeared to make economic sense.

The LR tests for the price and income homogeneity restrictions reported in the first and third panels of Table 5 indicate that both restrictions are rejected at the 0.05 significance level, implying that the neutrality

hypothesis of money is not a valid restriction on the Greek data.[6]

Model (6) has been reestimated under the hypothesis that the constant term is absent from the regressors. This implies that $\alpha_0$ is now appearing in model (6). The obtained results which reported in the second and fourth panels of Table (3), indicate that the hypothesis that there are two cointegrating vectors is accepted for both m1 and m3, although, as before, only the second vector bore the correct signs. By normalizing on that vector, we get:

$$m1=-3.84+0.84p+1.21y-0.02R \tag{9}$$

and,

$$m3=-2.44+1.21p+0.84y-0.01R \tag{10}$$

The LR tests for both set of restrictions reported in the second and fourth panels of Table (5), strongly confirm those obtained before, suggesting that the money is not neutral in Greece.

Model (7) has then tested for cointegration and the results are reported in Table (4). The LR calculated statistics reported in the first and third panels of Table (4) show that the hypothesis that more than two cointegrating vectors are present is accepted at the 95% confidence level for both m1 and m3. However, there seemed to be only one (two) vector whose signs made economic sense in the case of M1 (M3).

By imposing the restriction on the constant term, the results which reported in the second and fourth panels of the Table (4) indicate that at least three but possibly four cointegrating vectors are present. However, it was only one vector whose signs bore economic sense in either case:

$$m1=-1.48+0.92p+1.99y-0.02R+0.23e \tag{11}$$

and,

$$m3=-3.18+1.66p+0.24y-0.06R+0.32e \tag{12}$$

It is worth noting that the long run elasticity of money demand with respect to the exchange rate is less than one for both m1 and m3. Moreover, the tested hypotheses of a unit coefficient on p and y have been rejected at the 0.05 significance level in both cases.

Having established that the Greek money demand data are consistent with the existence of only one economically meaningful cointegrating vector, then the following EC model as suggested by Wickens and Breusch (1988) is used to test the statistical significance of the long run multipliers:

$$m_t=\alpha+\beta p_t+\gamma y_t-\delta R_t+\zeta e_t+\sum_{i=1}^{q} f'\Delta x_{t-i}+v_t \tag{13}$$

where **f** is a 5x1 vector of parameters and $\mathbf{x}'=(m\ p\ y\ R\ \varepsilon)$

is a 1x5 vector of variables; $v_t \sim IN(0,\sigma^2_v)$. Since the money demand variables are cointegrated, OLS will provide consistent estimates of the long run parameters (Stock, 1987). To achieve full efficiency, it is necessary to include lagged variables as well (Wickens and Bruesch, 1988). The results are presented in Tables 7 and 8. On inspection it is observed that: First, the interest rate elasticity of the narrow money demand is not statistically significant thus questioning the adoption of M1 as a monetary target.

Second, the elasticity of the broad money demand with respect to the interest rate is statistically significant at the 0.05 level, implying that the aggregate is subject to control through policy-induced interest rate movements, and thus serves as a useful target for the conduct of the Greek monetary policy.

Third, the elasticies of m1 and m3 with respect to ε are both statistically significant suggesting that capital controls applied over the sample period were not highly effective. Furthermore, monetary authorities by operating on the exchange rate will affect the demand for money.

Fourth, the estimated long run parameters do not appear much different from those obtained from Johansen's approach, with the exception of the real income elasticity of m3 which is now greater than one.

Finally, the tested price and income homogeneity restrictions are rejected in all cases, with the exception of m1 when model (7) used. In this case, the price homogeneity restriction could not be rejected, which is not consistent with the results obtained from Johansen and Juselius (1990) approach.

The diagnostic tests reject the presence of serial correlation, functional misspecification and heteroscedasticity at the 0.05 significance level. Furthermore, the normality test suggests that the error process presents a random sample from a normal distribution.

In a recent paper, Phillips and Hansen (1990) have argued that the instrumental variable estimator does not eliminate the asymptotic bias, when there is endogeneity in the regressors of a cointegrating equation. Instead, they have developed a fully-modified semi-parametric approach, as an alternative to the EC methodology, which corrects for the presence of endogeneity and serial correlation.[7] They have also developed a fully-modified Wald statistic to test linear restrictions about the coefficients in the cointegrating equation.

The Phillips-Hansen (1990) approach is now being used to allow for the presence of endogeneity in the money demand equations. The results are reported in Tables 9 and 10.[8] On inspection it is observed that the results are similar to those obtained from the EC methodology with the exception of the real income elasticity of money demand which is less than one. The modified Wald tests have also rejected the joint price and income homogeneity restrictions in all cases, with the exception of m1 when model (7) used. As before, the unit price elasticity of the narrow money demand could not be rejected.

## IV. CONCLUSIONS

This paper has concentrated on the analysis of the long run money demand functions for M1 and M3 in Greece. The evidence provided by means of Johansen's (1988) cointegration methodology, suggested that there exists an economically meaningful cointegrating vector for the money demand data. Moreover, the EC and Phillips-Hansen (1990) approaches indicated that the narrow money demand is interest inelastic. One implication of these findings is that shocks which affect M3 (M1) are reflected on prices, output, interest rates and the exchange rate (prices, output, and the exchange rate) in a similar way, implying that movements in M3 (M1) will be closely associated with changes in P, Y, R and ε (P, Y and ε), thus obeying an equilibrium constraint. The rejection of the price level homogeneity restriction in most cases suggests that money is not neutral in Greece. Moreover, the statistical significance of the interest rate elasticity of the broad money demand implies that M3 can serve as a useful intermediate monetary target for the conduct of Greek monetary policy, since the aggregate is subject to control through policy-induced interest rate movements.

## NOTES

1. The distribution of the DF test is not however invariant with respect to the presence of a nonzero mean or a time trend (Dickey and Fuller, 1979). Dickey et al., (1986) recommended against the inclusion of a time trend into (1), since such an inclusion would make a random walk model look stationary, with DF test having low power.

2. The calculation of the eigenvectors of $S_{q0}S_{00}^{-1}S_{0q}$ with respect to $S_{qq}$ can be transformed into a standard eigenvalue problem by using Choleski decomposition $S_{qq}=CC'$, since the eigenvalues that solve $|\lambda S_{qq}-S_{q0}S_{00}^{-1}S_{0q}|$ also solve $|\lambda I-C^{-1}S_{q0}S_{00}^{-1}S_{0q}C'^{-1}|=0$. Premultiplying the eigenvectors of the standardized problem by $C'^{-1}$, one can obtain the original eigenvectors normalized such that $E'S_{qq}E=I$. The calculations of the eigenvectors have been performed using the computer package RATS 3.0, VAR Econometrics, Inc/Doan Associates.

3. When the inflation rate included in model (6) to proxy the opportunity cost, calculations were abandoned due to the presence of multicollinearity.

4. The data for M1, M3, and R have been obtained from Bank of Greece's Monthly Statistical Bulletin, various issues. The data for the effective exchange rate was kindly provided from the economic research department of the Bank of Greece. The data for Y and P are taken from the National Accounts of Greece, February 1989, and IMF's International Financial Statistics, various issues respectively.

5. The rejection of a unit root in the level of real income based on PP test is due to the presence of a nonzero mean ($Z_{tb}$=5.09).

6. As Johansen and Juselius (1990) have shown, the hypothesis $H_0:\Phi=H\Theta$ specifies the same restrictions on all the cointegrating vectors.

7. Phillips and Hansen (1990) have discussed the cases under which the two approaches are asymptotically equivalent.

8. The Phillips-Hansen (1990) methodology was applied by using the econometric package written by P. Burridge of the University of Birmingham, to whom I am too much obliged.

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TABLE 1

*Unit Root Tests*

| V/bles | Dickey-Fuller $\tau_A$ | Phillips-Perron $Z(\tau_A)$ |
|---|---|---|
| m1 | -0.572[1]<br>(4.74) | -0.41 |
| m3 | -0.33[4]<br>(4.30) | -0.31 |
| p | 0.59[1]<br>(3.75) | 0.52 |
| y | -2.55[2]<br>(6.42) | -5.07 |
| R | -0.68[2]<br>(1.77) | -0.63 |
| ε | 1.138[0]<br>(0.23) | 1.29 |
| Δm1 | -11.45[0]<br>(4.38) | -11.36 |
| Δm3 | -4.15[3]<br>(4.32) | -5.95 |
| Δp | -4.17[0]<br>(4.00) | -8.95 |
| Δy | -7.30[1]<br>(4.50) | -9.08 |
| ΔR | -6.08[1]<br>(2.27) | -5.98 |
| Δε | -6.88[0]<br>(0.52) | -5.23 |

Notes: Figures in squared brackets denote the number of lagged dependent variables in the regression. The selection between zero and nonzero lags was based on the Lagrange multiplier(LM) test for fourth-order serial correlation of the residuals. Figures in parentheses refer to the values of the LM(4) statistic. The rest of the entries are the values of the unit root tests, the critical value of which at the 0.05 level is -2.93 for T=50 (Fuller,1976, p.373).

TABLE 2

*Q-Test and Lag Order of Model:*

$$\Delta X_t=d_0+d_1\Delta X_{t-1}+\ldots+d_{q-1}\Delta X_{t-q+1}+d_q X_{t-q}+\mu' D_{1t}+\omega_t$$

Dep. V/ble: ΔX

| Indep. Lagged V/bles | Δm1 | Δp | Δy | ΔR | Δε |
|---|---|---|---|---|---|
| ΔX | 2 | 2 | 2 | 2 | - |
| X | 3 | 3 | 3 | 3 | - |
| Q(21) | 28.80 | 16.47 | 16.42 | 17.95 | - |
| | [0.12] | [0.75] | [0.75] | [0.65] | |
| ΔX | 3 | 3 | 3 | 3 | 3 |
| X | 4 | 4 | 4 | 4 | 4 |
| Q(21) | 32.51 | 12.24 | 19.85 | 19.32 | 18.59 |
| | [0.06] | [0.93] | [0.53] | [0.57] | [0.61] |

Dep. V/ble: ΔX

| Indep. Lagged V/bles | Δm3 | Δp | Δy | ΔR | Δε |
|---|---|---|---|---|---|
| ΔX | 3 | 3 | 3 | 3 | - |
| X | 4 | 4 | 4 | 4 | - |
| Q(21) | 26.92 | 23.00 | 23.15 | 9.52 | - |
| | [0.17] | [0.34] | [0.34] | [0.98] | |
| ΔX | 3 | 3 | 3 | 3 | 3 |
| X | 4 | 4 | 4 | 4 | 4 |
| Q(21) | 24.84 | 11.28 | 26.85 | 14.21 | 17.95 |
| | [0.25] | [0.96] | [0.18] | [0.86] | [0.65] |

Notes: Q(21) denotes the Ljung-Box (1978) Q-statistic for residuals autocorrelation at 21 degrees of freedom. Figures in squared brackets are the marginal significance levels (MSLs) of Q.

*TABLE 3*

*Cointegration Tests for the Demand for Money*

Model: $m1=\beta_0 p+\gamma_0 y-\delta_0 R$

| Eigenvectors | r=0 | r≤1 | r≤2 | r≤3 | r≤4 |
|---|---|---|---|---|---|
| Trace | 56.65 | 31.79 | 11.74 | 2.67 | - |
| Critical value (0.95) | 48.419 | 31.256 | 17.844 | 8.083 | - |
| Maximal Eigenvalue | 24.86 | 20.05 | 9.07 | 2.67 | - |
| Critical Value (0.95) | 27.341 | 21.279 | 14.595 | 8.083 | - |

Model: $m1=\alpha_0+\beta_0 p+\gamma_0 y-\delta_0 R$

| Eigenvectors | r=0 | r≤1 | r≤2 | r≤3 | r≤4 |
|---|---|---|---|---|---|
| Trace | 99.05 | 39.80 | 18.98 | 6.06 | - |
| Critical value (0.95) | 53.347 | 35.068 | 20.168 | 9.094 | - |
| Maximal Eigenvalue | 59.25 | 20.82 | 12.92 | 6.06 | - |
| Critical Value (0.95) | 28.167 | 21.894 | 15.752 | 9.094 | - |

Model: $m3=\beta_0 p+\gamma_0 y-\delta_0 R$

| Eigenvectors | r=0 | r≤1 | r≤2 | r≤3 | r≤4 |
|---|---|---|---|---|---|
| Trace | 85.26 | 42.22 | 9.84 | 1.55 | - |
| Maximal Eigenvalue | 43.04 | 32.38 | 8.29 | 1.55 | - |

Model: $m3=\alpha_0+\beta_0 p+\gamma_0 y-\delta_0 R$

| Eigenvectors | r=0 | r≤1 | r≤2 | r≤3 | r≤4 |
|---|---|---|---|---|---|
| Trace | 92.33 | 46.86 | 11.51 | 2.62 | - |
| Maximal Eigenvalue | 45.47 | 35.35 | 8.89 | 2.62 | - |

Notes: Critical values are taken from Johansen and Juselius (1990, Table A.2 and A.3).

*TABLE 4*

*Cointegration Tests for the Demand for Money*

Model: $m1=\beta_1 p+\gamma_1 y-\delta_1 R+\zeta_1 \varepsilon$

| Eigenvectors | r=0 | r≤1 | r≤2 | r≤3 | r≤4 |
|---|---|---|---|---|---|
| Trace | 112.24 | 65.51 | 32.16 | 10.97 | 2.08 |
| Critical value (0.95) | 69.977 | 48.419 | 31.256 | 17.844 | 8.083 |
| Maximal Eigenvalue | 46.73 | 33.35 | 21.19 | 8.89 | 2.08 |
| Critical Value (0.95) | 33.262 | 27.341 | 21.279 | 14.595 | 8.083 |

Model: $m1=\alpha_1+\beta_1 p+\gamma_1 y-\delta_1 R+\zeta_1 \varepsilon$

| Eigenvectors | r=0 | r≤1 | r≤2 | r≤3 | r≤4 |
|---|---|---|---|---|---|
| Trace | 124.46 | 73.75 | 40.4 | 19.21 | 3.16 |
| Critical value (0.95) | 69.977 | 53.347 | 35.068 | 20.168 | 9.094 |
| Maximal Eigenvalue | 50.71 | 33.35 | 21.19 | 16.05 | 3.16 |
| Critical Value (0.95) | 33.262 | 28.167 | 21.894 | 15.752 | 9.094 |

Model: $m3=\beta_1 p+\gamma_1 y-\delta_1 R+\zeta_1 \varepsilon$

| Eigenvectors | r=0 | r≤1 | r≤2 | r≤3 | r≤4 |
|---|---|---|---|---|---|
| Trace | 131.9 | 79.8 | 35.56 | 5.99 | 0.05 |
| Maximal Eigenvalue | 52.1 | 44.24 | 29.57 | 5.94 | 0.05 |

Model: $m3=\alpha_1+\beta_1 p+\gamma_1 y-\delta_1 R+\zeta_1 \varepsilon$

| Eigenvectors | r=0 | r≤1 | r≤2 | r≤3 | r≤4 |
|---|---|---|---|---|---|
| Trace | 140.5 | 88.4 | 39.05 | 8.56 | 2.62 |
| Maximal Eigenvalue | 52.10 | 49.35 | 30.49 | 5.94 | 2.62 |

Notes: See notes to Table 3.

### *TABLE 5*
### *LR-Statistics for Testing Long Run Price and Income Homogeneity*

Model: $m1=\beta_0 p+\gamma_0 y-\delta_0 R$

| Tested Restrictions | Eigenvalues | LR-test | $X^2_{r(n-s)}$ |
|---|---|---|---|
| - | (0.38 0.32 0.16 0.05) | - | - |
| $H_0^1: \beta_0=1$ | (0.37 0.20 0.06 ) | 9.88 | 2 |
| $H_0^2: \beta_0=\gamma_0=1$ | (0.32 0.06 ) | 21.84 | 4 |

Model: $m1=\alpha_0+\beta_0 p+\gamma_0 y-\delta_0 R$

| Tested Restrictions | Eigenvalues | LR-test | $X^2_{r(n-s)}$ |
|---|---|---|---|
| - | (0.68 0.33 0.22 0.11 0) | - | - |
| $H_0^1: \beta_0=1$ | (0.62 0.29 0.20 0.01 ) | 11.96 | 2 |
| $H_0^2: \beta_0=\gamma_0=1$ | (0.61 0.27 0.01 ) | 15.08 | 4 |

Model: $m3=\beta_0 p+\gamma_0 y-\delta_0 R$

| Tested Restrictions | Eigenvalues | LR-test | $X^2_{r(n-s)}$ |
|---|---|---|---|
| - | (0.57 0.47 0.15 0.03) | - | - |
| $H_0^1: \beta_0=1$ | (0.51 0.25 0.03 ) | 23.97 | 2 |
| $H_0^2: \beta_0=\gamma_0=1$ | (0.39 0.05 ) | 47.43 | 4 |

Model: $m3=\alpha_0+\beta_0 p+\gamma_0 y-\delta_0 R$

| Tested Restrictions | Eigenvalues | LR-test | $X^2_{r(n-s)}$ |
|---|---|---|---|
| - | (0.59 0.50 0.16 0.05 0) | - | - |
| $H_0^1: \beta_0=1$ | (0.56 0.25 0.06 0 ) | 23.97 | 2 |
| $H_0^2: \beta_0=\gamma_0=1$ | (0.45 0.10 0 ) | 44.37 | 4 |

Notes: Figures in the last column denote the number degrees of freedom of $X^2_{r(n-s)}$ statistic.

### *TABLE 6*
### *LR-Statistics for Testing Long Run Price and Income Homogeneity*

Model: $m1=\beta_1 p+\gamma_1 y-\delta_1 R+\zeta_1 \varepsilon$

| Tested Restrictions | Eigenvalues | LR-test | $X^2_{r(n-s)}$ |
|---|---|---|---|
| - | (0.60 0.48 0.34 0.16 0.04) | - | - |
| $H_0^1: \beta_0=1$ | (0.50 0.38 0.23 0.11 ) | 28.56 | 3 |
| $H_0^2: \beta_0=\gamma_0=1$ | (0.46 0.27 0.16 ) | 45.39 | 6 |

Model: $m1=\alpha_1+\beta_1 p+\gamma_1 y-\delta_1 R+\zeta_1 \varepsilon$

| Tested Restrictions | Eigenvalues | LR-test | $X^2_{r(n-s)}$ |
|---|---|---|---|
| - | (0.63 0.48 0.34 0.27 0.06 0) | - | - |
| $H_0^1: \beta_0=1$ | (0.50 0.41 0.32 0.14 0.02 ) | 23.46 | 3 |
| $H_0^2: \beta_0=\gamma_0=1$ | (0.47 0.36 0.20 0.02 ) | 39.27 | 6 |

Model: $m3=\beta_1 p+\gamma_1 y-\delta_1 R+\zeta_1 \varepsilon$

| Tested Restrictions | Eigenvalues | LR-test | $X^2_{r(n-s)}$ |
|---|---|---|---|
| - | (0.64 0.58 0.44 0.11 0.01) | - | - |
| $H_0^1: \beta_0=1$ | (0.59 0.47 0.16 0.10 ) | 39.78 | 3 |
| $H_0^2: \beta_0=\gamma_0=1$ | (0.51 0.27 0.14 ) | 56.10 | 6 |

Model: $m3=\alpha_1+\beta_1 p+\gamma_1 y-\delta_1 R+\zeta_1 \varepsilon$

| Tested Restrictions | Eigenvalues | LR-test | $X^2_{r(n-s)}$ |
|---|---|---|---|
| - | (0.64 0.62 0.45 0.11 0.05 0) | - | - |
| $H_0^1: \beta_0=1$ | (0.62 0.47 0.19 0.10 0.02 ) | 39.78 | 3 |
| $H_0^2: \beta_0=\gamma_0=1$ | (0.51 0.33 0.14 0.02 ) | 66.81 | 6 |

Notes: See notes to Table 4.

### *TABLE 7*
### *Empirical Estimates and Diagnostics of Model:*

$$m=\alpha+\beta p_t+\gamma y_t-\delta R_t+\sum_{i=1}^{q} f'\Delta x_{t-1}+v_t$$

---

$$m1_t = \underset{[0.91]^*}{-4.24} + \underset{[0.03]^*}{0.76}p_t + \underset{[0.22]^*}{1.33}y_t - \underset{[0.006]}{0.002}R_t + \underset{[0.17]}{0.15}\Delta m1_{t-1} +$$

$$+\underset{[0.17]^*}{0.33}\Delta m1_{t-2} - \underset{[0.56]^*}{0.04}\Delta p_{t-1} - \underset{[0.28]^*}{0.18}\Delta y_{t-1} + \underset{[0.02]}{0.02}\Delta R_{t-1}$$

$R^2=0.9972, SEE=0.0366$

$$X^2_{SC}(4)=\underset{\{>.20\}}{4.97}, X^2_{SC}(12)=\underset{\{>.30\}}{13.11}, X^2_{FF}(1)=\underset{\{<.05\}}{10.05}$$

$$X^2_{NO}(2)=\underset{\{>.50\}}{0.85}, X^2_{HE}(1)=\underset{\{>.50\}}{0.21}, X^2_{ARCH}(12)=\underset{\{>.30\}}{11.88}, X^2_{PF}(11)=\underset{\{>.80\}}{5.95}$$

---

$$m3_t = \underset{[0.91]^*}{-4.61} + \underset{[0.03]^*}{1.17}p_t + \underset{[0.22]^*}{1.33}y_t - \underset{[0.005]^*}{0.02}R_t - \underset{[0.49]}{0.06}\Delta m3_{t-1} +$$

$$+\underset{[0.46]^*}{1.36}\Delta m3_{t-2} - \underset{[0.53]^*}{1.03}\Delta p_{t-1} - \underset{[0.25]}{0.26}\Delta y_{t-1} + \underset{[0.01]^*}{0.02}\Delta R_{t-1}$$

$R^2=0.9989, SEE=0.032$

$$X^2_{SC}(4)=\underset{\{>.30\}}{7.75}, X^2_{SC}(12)=\underset{\{>.20\}}{15.40}, X^2_{FF}(1)=\underset{\{>.05\}}{2.97}$$

$$X^2_{NO}(2)=\underset{\{>.95\}}{0.02}, X^2_{HE}(1)=\underset{\{>.30\}}{0.91}, X^2_{ARCH}(12)=\underset{\{>.30\}}{12.31}, X^2_{PF}(11)=\underset{\{>.70\}}{7.66}$$

---

Notes: Subscripts SC,FF,NO, and HE correspond to the test statistics for serial correlation, functional misspecification, normality and heteroscedasticity respectively. The predictive failure (PF) test conducted over the period 1986.1-1988.3. The ARCH test refers to autoregressive conditional heteroscedasticity. Figures in squared brackets are standard errors. Figures in braces are MSLs. An asterisk (*) denotes significance at the 0.05 level.

### *TABLE 8*
### *Empirical Estimates and Diagnostics of Model:*

$$m=\alpha+\beta p_t+\gamma y_t-\delta R_t+\zeta\varepsilon_t+\sum_{i=1}^{q} f'\Delta x_{t-i}+v_t$$

---

$$m1_t = \underset{[0.94]^*}{-5.90} + \underset{[0.07]^*}{0.93}p_t + \underset{[0.20]^*}{1.35}y_t - \underset{[0.007]}{0.12}R_t + \underset{[0.07]^*}{0.19}\varepsilon_t +$$

$$-\underset{[0.15]}{0.07}\Delta m1_{t-1} + \underset{[0.58]}{0.09}\Delta p_{t-1} - \underset{[0.27]}{0.01}\Delta y_{t-1}$$

$$+\underset{[0.01]}{0.03}\Delta R_{t-1} - \underset{[0.15]}{0.09}\Delta\varepsilon_{t-1}$$

$R^2=0.99, SEE=0.035$

$$X^2_{SC}(4)=\underset{\{>.50\}}{3.35}, X^2_{SC}(12)=\underset{\{>.30\}}{13.65}, X^2_{FF}(1)=\underset{\{>.05\}}{3.49}$$

$$X^2_{NO}(2)=\underset{\{>.50\}}{0.77}, X^2_{HE}(1)=\underset{\{>.70\}}{0.05}, X^2_{ARCH}(12)=\underset{\{>.50\}}{10.89}, X^2_{PF}(11)=\underset{\{>.90\}}{4.74}$$

---

$$m3_t = \underset{[0.90]^*}{-6.21} + \underset{[0.07]^*}{1.30}p_t + \underset{[0.19]^*}{1.37}y_t - \underset{[0.007]^*}{0.172}R_t + \underset{[0.07]^*}{0.17}\varepsilon_t +$$

$$-\underset{[0.45]}{0.28}\Delta m3_{t-1} + \underset{[0.44]}{0.90}\Delta m3_{t-2} - \underset{[0.51]}{0.99}\Delta p_{t-1} - \underset{[0.47]}{1.08}\Delta p_{t-2}$$

$$-\underset{[0.24]}{0.06}\Delta y_{t-1} + \underset{[0.24]}{0.50}\Delta y_{t-2} + \underset{[0.01]}{0.03}\Delta R_{t-1} - \underset{[0.09]}{0.05}\Delta R_{t-2}$$

$$-\underset{[0.13]}{0.06}\Delta\varepsilon_{t-1} + \underset{[0.13]}{0.03}\Delta\varepsilon_{t-2}$$

$R^2=0.99, SEE=0.0286$

$$X^2_{SC}(4)=\underset{\{>.20\}}{5.10}, X^2_{SC}(12)=\underset{\{>.30\}}{13.37}, X^2_{FF}(1)=\underset{\{>.30\}}{0.89}$$

$$X^2_{NO}(2)=\underset{\{>.70\}}{0.65}, X^2_{HE}(1)=\underset{\{>.80\}}{0.03}, X^2_{ARCH}(12)=\underset{\{>.80\}}{7.16}, X^2_{PF}(11)=\underset{\{>.50\}}{9.01}$$

---

Notes: See notes to Table 7.

*TABLE 9*

*Phillips-Hansen Modified Estimates of Model:*

$$m=\alpha_0+\beta_0 p_t+\gamma_0 y_t-\delta_0 R_t+u_{0t}$$

---

$$m1_t = \underset{[0.34]}{-0.72} + \underset{[0.03]}{0.82p_t} + \underset{[0.08]}{0.49y_t} + \underset{[0.007]}{0.009R_t}$$

$R^2 = 0.99$, $PP(8) = -3.90$ {<.10}

| Tested Restrictions | Wald-Test |
|---|---|
| $H_0^1$: $\beta_0=0$ | $X^2(1)=777.80$<br>{<.01} |
| $H_0^2$: $\gamma_0=0$ | $X^2(1)=36.31$<br>{<.01} |
| $H_0^3$: $\delta_0=0$ | $X^2(1)=1.43$<br>{>.20} |
| $H_0^4$: $\beta_0=1$ | $X^2(1)=37.86$<br>{<.01} |
| $H_0^5$: $\beta_0=\gamma_0=1$ | $X^2(2)=103.59$<br>{<.01} |

---

$$m3_t = \underset{[0.35]}{-0.48} + \underset{[0.03]}{1.27p_t} + \underset{[0.08]}{0.34y_t} - \underset{[0.007]}{0.01R_t}$$

$R^2 = 0.99$, $PP(8) = -3.79$ {<.10}

| Tested Restrictions | Wald-Test |
|---|---|
| $H_0^1$: $\beta_0=0$ | $X^2(1)=1711.7$<br>{<.01} |
| $H_0^2$: $\gamma_0=0$ | $X^2(1)=15.63$<br>{<.01} |
| $H_0^3$: $\delta_0=0$ | $X^2(1)=2.73$<br>{<.10} |
| $H_0^4$: $\beta_0=1$ | $X^2(1)=79.15$<br>{<.01} |
| $H_0^5$: $\beta_0=\gamma_0=1$ | $X^2(2)=106.69$<br>{<.01} |

---

Notes: Figures in squared brackets are asymptotic standard errors. Figures in braces are MSLs. PP(8) denotes the PP unit root test with lag length equals to 8.

*TABLE 10*

*Phillips-Hansen Modified Estimates of Model:*

$$m=\alpha_1+\beta_1 p_t+\gamma_1 y_t-\delta_1 R_t+\zeta_1\varepsilon+u_{1t}$$

---

$$m1_t = \underset{[0.86]}{-2.14} + \underset{[0.09]}{0.97p_t} + \underset{[0.07]}{0.47y_t} + \underset{[0.007]}{0.001R_t} + \underset{[0.11]}{0.19\varepsilon_t}$$

$R^2 = 0.9947$, $PP(8) = -4.20$ {<.05}

| Tested Restrictions | Wald-Test |
|---|---|
| $H_0^1$: $\beta_1=0$ | $X^2(1)=124.21$<br>{<.01} |
| $H_0^2$: $\gamma_1=0$ | $X^2(1)=40.86$<br>{<.01} |
| $H_0^3$: $\delta_1=0$ | $X^2(1)=0.02$<br>{>.80} |
| $H_0^4$: $\zeta_1=0$ | $X^2(1)=3.37$<br>{<.10} |
| $H_0^5$: $\beta_1=1$ | $X^2(1)=0.09$<br>{>.70} |
| $H_0^6$: $\beta_1=\gamma_1=1$ | $X^2(2)=55.46$<br>{<.01} |

---

$$m3_t = \underset{[0.89]}{-2.25} + \underset{[0.09]}{1.47p_t} + \underset{[0.08]}{0.31y_t} - \underset{[0.008]}{0.03R_t} + \underset{[0.10]}{0.23\varepsilon_t}$$

$R^2 = 0.9965$, $PP(8) = -4.09$ {<.10}

| Tested Restrictions | Wald-Test |
|---|---|
| $H_0^1$: $\beta_1=0$ | $X^2(1)=263.41$<br>{<.01} |
| $H_0^2$: $\gamma_1=0$ | $X^2(1)=16.85$<br>{<.01} |
| $H_0^3$: $\delta_1=0$ | $X^2(1)=8.20$<br>{<.01} |
| $H_0^4$: $\zeta_1=0$ | $X^2(1)=4.85$<br>{<.05} |
| $H_0^5$: $\beta_1=1$ | $X^2(1)=26.79$<br>{<.01} |
| $H_0^6$: $\beta_1=\gamma_1=1$ | $X^2(2)=97.17$<br>{<.01} |

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Notes: See notes to Table 9.

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